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**UTILIZATION CONDITIONS OF DIFFERENT TYPES OF AIRPLANES.**

**By De Marolles.**

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## UTILIZATION CONDITIONS OF DIFFERENT TYPES OF AIRPLANES.\*

By De Marolles.

There are many possible ways of comparing different airplane types. By way of illustration, we are going to examine a concrete problem showing how important such a comparison may be.

In order to make this comparison more readily, it is convenient to resort to a method of presentation a little different from that of the customary polars. This method consists in taking for the abscissas the equation  $\lambda = \sqrt{\frac{K_{y\max}}{K_y}}$ . It is then obvious that this equation is equal to  $V/V_a$ , or, in other words, that the scale of the abscissas is a scale of speeds, the landing speed  $V_a$  being taken as unity. For ordinates, we take the values of the quantity  $N = \frac{K_x}{K_y} \lambda$ . From this equation there is readily derived a second scale of ordinates  $t$ , which gives the HP/kg required in terms of the speeds.

If, for example, the landing speed chosen is  $V_a = 100$  km/hr, it is obvious that the airplane, whose characteristic curve is A, requires, for flying at 150 km/hr, a power of 0.066 HP/kg, while the airplane of curve B requires only 0.05 HP/kg. A juxtaposed scale gives the inverse values  $n$ , (kg/HP), the unit more generally employed.

In fact, this method of presentation clearly shows the difference in the speed of an airplane in terms of its excess power and indicates above what speed one type of airplane is better than another.

Curves A and B show the speed of two typical airplanes.

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A is a biplane with the customary style of fuselage, with thin wings and an aspect ratio of 6. B is a commercial monoplane with a thick wing, without struts or wires, and with an aspect ratio of 9 to 10.

These curves are only intended to bring out the difference between two clearly distinct types of existing airplanes.

From the indications given by these curves, we can readily deduce the characteristics of a similar airplane that will satisfy any given conditions.

Represent by:

$P$  = kg, total weight of airplane in flying order;

$P_u$  = kg, total load carried;

$\omega$  = kg/HP, weight of power plant;

$o$  = kg/HP/h, weight of fuel corresponding to the normal cruising speed;

$\dot{T}$  = HP, maximum motive power of engine;

$h$  = coefficient of utilization of motive power at cruising speed;

$\eta$  = propeller efficiency;

$\mu$  = coefficient of weight of type of construction adopted;

$V_T$  = km/hr, cruising speed (corresponding to the cruising motive power  $hT$ );

$V_a$  = km/hr, landing speed;

$L$  = km, maximum radius of action at  $V_T$  with no wind.

First we have  $\lambda_T = V / V_T$ , whence, by the curve, the number of kg/HP, ( $n$ ) to be carried by the airplane, with engine at cruising speed  $hT$ , whence

$$\frac{P}{hT} = n, \text{ or } T = \frac{nh}{P}.$$

On the other hand, the quantity of fuel to be carried corresponds to a period of flight:

$$D = \frac{L}{V_T}$$

The weight  $P_m$  of the power plant with  $D$  hours of fuel is therefore

$$P_m = T (\omega + D \phi h)$$

The total weight  $P$  is given by the equation

$$P = \frac{P_m + P_u}{\mu}$$

$\mu$  being the coefficient of weight of the type of airplanes. In fact, this equation is not exact. It gives, however, close enough approximations in practice, if the dimensions of the airplane to be constructed do not differ much from those of the type chosen as its basis.

We then have:

$$P = \frac{T(\omega + D\phi h + P_u)}{\mu}$$

whence

$$T = \frac{P_u}{n \phi h \mu - (\omega + D\phi h)}$$

As to the surface area, calling  $K_{y_{\max}}$  the maximum lift, it has a value of

$$S = \frac{P}{K_{y_{\max}} V_a^2}$$

Thus the general characteristics are determined. The problem, however, is not always possible. The condition is:

$$n \rho h \mu - (\omega + Dch) > 0$$

It is not always possible, however, to make an airplane similar to a given model, to carry a certain load at a stipulated speed over a fixed course. Outsiders are apt to think that the problem can always be solved, even at the expense of efficiency, by considering the horsepower and the square meters. Such is not the case however and  $\omega$  or  $c$  must be diminished, in order to render the problem solvable, considering that, in the inequality  $n \rho h \mu > \omega + Dch$ , the first member does not vary in a concrete case. If these reductions do not suffice, another type of airplane must be sought which carries more per HP (increase of  $n$  in first member).

For illustration and to show the practical influence of the coefficient of construction  $\mu$ , let us take the following case:

An air traffic company desires an airplane of moderate speed for the exclusive transportation of freight. It stipulates a cruising speed of  $V_r = 150$  km/hr, while asking, however, that the calculation be also made for speeds  $V_r$  of 175 and 200 km/hr for the purpose of comparing the net cost at the different speeds. The landing speed is not to exceed 100 km/hr. The altitude limit at the start must be at least 4000 m. Carrying capacity including crew, 1000 kg. The fuel load must be sufficient for a radius of action of 600 km in calm air.

The coefficient of utilization of the power at cruising speed is  $h = 0.9$ . Propeller efficiency  $\eta = 0.75$ . Weight of engines is  $\omega = 1500$  kg/HP. Fuel consumption  $c = 0.25$  kg/HP/hr.

Calculations, made in accordance with the above method, produce the results given in the following table,  $\mu$  being 0.7 for type A and 0.6 for type B.

V - Km/hr	150		175		200	
Type of airplane . . . .	A	B	A	B	A	B*
n kgs/HP . . . . .	15.3	20	11.5	11.7	8.35	5.6
T HP . . . . .	208	176	316	408	565	11700
P kgs . . . . .	2140	2375	2460	3200	3180	44000
Z m . . . . .	1050	3400	2700	6050	4500	10000

By consulting only the curves, it would appear that, from the simple aerodynamic point of view, type A becomes preferable to type B for  $V > 178$  km/hr. The results obtained for  $V_T = 180$  km/hr would therefore be practically equal.

Results show that, by reason of variations in the coefficient  $\mu$ , equality is obtained for about 165 km/hr, only the question of speed entering into consideration. But, if we draw the curve of the "ceilings," we find that type A would give the stipulated ceiling at the start only in excess of  $V_T = 190$  km/hr. On the contrary, type B gives the required ceiling at  $V_T = 156$  km/hr.

\* Figures given only by way of example, since formula (2) no longer applies for these values.

In short, of the types chosen, B must be given the preference and must be computed for a speed of 156 km/hr or more.

Above  $V_T = 190$  km/hr, type A would be accepted without discussion. Between 180 and 190 km/hr neither type would be acceptable. A would not give the required ceiling and B would require too much power. It would be necessary either to find a third more appropriate type, or use A after increasing its surface area. In the latter case, the power necessary for a given speed would be increased.

A variation of only a few kilometers per hour leads therefore to a radical transformation of the type of airplane required. This is the important point.

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